Changes in Composition and Diversity of an Urban Bottomland Forest over Time

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ABSTRACT

The loss of biodiversity has been major conservation concern around the world as a result of urbanization, increasing deforestation, and agriculture use. This project aims to inventory and assess the vegetative diversity of a local 12 acre bottomland hardwood forest community located in the Schiermeier Olentangy River Wetlands Park and historical forest data that was summarized from original public land survey records. Biodiversity surveys were conducted in two parts, with trees and herbaceous surveys completed in fall 2014 and another herbaceous survey completed in spring 2015. Shannon's diversity index was calculated using species presence and absence data. Results from both surveys found a mean diversity of 2.07 for the forest community with diversity between the surveys not significantly different. The comparison between current and historical tree diversity was shown to be significantly different ($p=0.001$) with the historical diversity being higher. This suggests that the forest composition has been drastically altered and the succession of the forest could have been influenced heavily by natural and anthropogenic factors. Studying forests under this condition provides a basis for managing fragmented forests with potential for improved health, amenities, and ecosystem services and processes in an urban landscape. Management options based on the analysis of historical and current data are discussed further within the paper.

INTRODUCTION

In the last 300 years, the landscape of North America has undergone extensive changes due to European settlement, and subsequently due to the Industrial Revolution resulting in greater urbanization of the population (Smith et al 2007). It is estimated that compared to the acreage of forest present in the United States before settlement, about 72% is still forested today (Fedkiw 1989). In the state of Ohio, is it estimated that 95% of the land was forested before European settlement and by the early 1900-s, this had dropped to less than 15% (ODNR Division of Forestry). Forest cover in Ohio has increased to over 30 percent since then, but this significant loss in forested habitat, as well as other natural habitats, has raised many concerns over the decline of species biodiversity within the United States and on a global scale as similar trends are being repeated worldwide (Groombridge and Jenkins 2002). Another trend of note is the rapid urbanization of land cover, which has increased 60% from 1950-2002 and expected to only continue growing (Smith et al 2007). The combination of these trends has led many to begin a new branch of biodiversity studies in urban environments and landscapes. Despite the preconceived notion urban environments could not support diverse ecosystems (Ordonez and Duniker 2012), many studies have found that urban forests contain relatively high levels of biodiversity (Jim and Liu 2001; Araujo 2003; Godefroid and Koedam 2003; Cornelis and Henry 2004; Kuhn et al 2004). Some of this is attributed to the high number of exotic and introduced species in urban landscaping (Alvey 2006, Ordonez and Duinker 2012) but evidence has been found of native and rare vegetative species which can survive and have self-sustaining populations in developed areas if the conditions are similar to their traditional habitats (Kowarik 2011).

Urban forest history and dynamics is a field of study which has often been neglected in the past (Loeb 2010). To determine the changes a forest has undergone, forest history is a tool which can be used to assess long-term change across a landscape and can be applied to determine diversity and the changes it undergoes through time. But urban forests face a set of unique factors and influences to their succession and composition (Beninde, Veith and Haochkirch 2015) that make an accurate prediction of the exact history and succession of the forest difficult to ascertain or predict. The fact that this study area in this project is a bottomland hardwood forest also adds to its complexity. A bottomland hardwood forest is influenced by many types of biological process such as hydrological factors, the frequency of disturbances, and the formation of biogeochemical mechanisms across time (Allen 2004). But these factors also can make riparian ecosystems are far more productive than other ecosystems due to the deposition of organic matter and other substrates that diversify vegetation (Tabacchi et al 1998), which in theory would create favorable conditions for biodiversity. However, human processes and influences can interrupt and change natural processes across the landscape. Human constructs, such as the levees and dams, can force wet lowlands to become much drier and make less favorable conditions for oxygen-depleted wet areas where rare species may thrive (Kowarik 2011). This is why diversity, especially in an urban bottomland hardwood forest, can become challenging.

Previous Studies of Site

The study site is located in the center of the city of Columbus, Ohio. The Schiermeier Olentangy River Wetlands, part of The Ohio State University, was established in 1994 and was formerly used for agricultural purposes before the university converted ~6 acres into fully functioning wetlands dependent on inflow from the Olentangy River. Next to the park is a 12 acre hardwood forest where this study has taken place. A unique feature of the forest is that it was never cleared for agriculture, even though it is not out of the realm of possibility that the forest was high-graded for timber sometime after European settlement. A few studies have been completed in the forest area, with topics ranging from basal area growth response to changes in the forest hydrology after removing constructed levees (Anderson and Mitsch 2008) to monitoring the effects of abundant *Lonicera* spp. on understory diversity present in the forest (Swab, Zhang and Mitsch 2008). There have been no studies, however, which sought to inventory the forest and determine the diversity and composition of the forest vegetation as a whole. Lippman and Mitsch (2001) conducted an overstory survey of trees species immediately following the release of the levees, but no survey of understory or herbaceous species was conducted. Swab 2008 conducted detailed understory surveys, but collected no data on trees. While the information from these studies could be combined to create a tree and understory species list, it would be difficult to determine diversity from the data sets due to their differing spatial and temporal distributions. Additionally, a vegetative survey was completed in 1998 to summarize the state of the bottomland forest before restoration efforts were to be implemented beginning in 2000 (Bouchard and Mitsch 1999). This will also be compared to the results of this study to estimate how much the forest has changed since "pre-restoration" conditions.

Objectives

This study hopes to create a more complete picture of diversity in the hardwood forest at given point in time by collecting overstory and understory data across the entire forest at the beginning and end of the growing season. This will create a profile of the current forest composition across space and time and provide a point of comparison for any future studies investigating the restoration of the forest. In approaching the analysis of diversity in this study, several dimensions were examined as described by Agnoletti 2000, such as determining the original landscape dynamics and composition, the scale at which diversity is being described, and the temporal dimension of diversity in both short term and long term will be considered and discussed. Using sources of historical documentation, one may derive vegetative, spatial, and cultural patterns that have influenced the composition and diversity of an ecosystem, even in an urban setting.

METHODS

Surveying

Two surveys were conducted, one in the early fall of 2014 and another in the spring of 2015. The fall survey focused on gathering tree data in addition to understory data while the spring survey focused on gathering only understory data. A grid of GPS points were projected over the study area, with 24 points indicating plot locations. In the first survey, tree and understory data were collected using two different plot sizes, using the GPS location as the plot center. Tree data were collected from a circular 0.17 acre plot. Within this plot all trees (defined to be >2 meter height) were measured by taking the diameter at breast height (dbh) in centimeters (cm). Understory data were measured in a circular 3 m^2 plot with the GPS location as the plot center. In the fall survey, individual stems were counted for individual species and the percent cover of vegetation, litter and bare ground was measured within the plot. The spring data collection only gathered understory data and was repeated at the same GPS points. Instead of individual stems being counted by species, percent cover of each species was recorded in addition to the

Historical Data Collection

Historical data were collected from original land survey documents from the 1797 U.S Military District land survey courtesy of the Ohio Historical Society. Descriptive data were gathered from surveyor notes and quantitative data were taken using notes on witness trees for the township section corners. Witness trees were identified to species and had the dbh recorded. However, only tree data were collected in historical documents and therefore no historical understory data were found to be compared with understory data from the surveys.

Data Analysis

Overall forest composition was assessed by calculating relative density, relative dominance and importance values for each species recorded. Relative density was calculated for each species by dividing the number of trees counted for that species divided by the total number of trees recorded. Relative dominance was the basal area calculated for each species divided by the total basal area of all trees recorded. Calculation of importance value for each species is shown in Equation 1.

(Equation 1). Importance value (by species) = (relative density + relative dominance)/2

Diversity of trees and understory were calculated with Shannon's diversity index using species presence and absence data. The diversity index value of each survey was calculated separately and then the surveys were combined to find the overall vegetative diversity of the forest. Diversity was also found for historical tree species and compared to the diversity of current trees. Due to the minimal amount of data which could be obtained from historical sources, this comparison of diversity was done by creating a randomly generated sample from the tree survey data set which contains the same number of trees found from historical records. The mean diversity of the sample and the historical data set was calculated using species presence and absence and the results were compared with a T-test.

To determine vegetative communities in the forest, cluster analysis was completed on each plot with the Bray-Curtis dissimilarity index. Plots were ordered based on their Bray-Curtis value and placed into distinct clusters based on their average similarity to each other. For each cluster, species compositions were analyzed to determine 'indicator species' of each cluster by calculating the occurrence of the species in the plots within the cluster.

RESULTS

Tree Importance Values

A total of 308 individuals compromised of 21 species of trees were recorded. Tree diversity had differing outcomes between current and historical surveys in density, dominance, and importance values. *Acer negundo* and *Aesculus glabra* had the highest importance values (16.7, 13.4) comparable to the other species present (Figure 1). This is then followed by *Populus deltoides* (10.7), *Juglans nigra* (10.3), *Celtis occidentalis* (8.9), *Maclura pomifera* (4.2), *Asimina triloba* (4.9), and *Platanus occidentalis (*4.7). Remaining species had importance values less than 4 and are not presented in figures but are represented in Appendix A. In the historical data set, *Fagus grandifolia* (41) is the most significant, followed by *Carya spp.* (19), *Ulmus rubra* (11), *Acer saccharum* (11), *Quercus alba* (5), *Quercus rubra* (10), *Acer spp* (2), and *Fraxinus spp* (2).

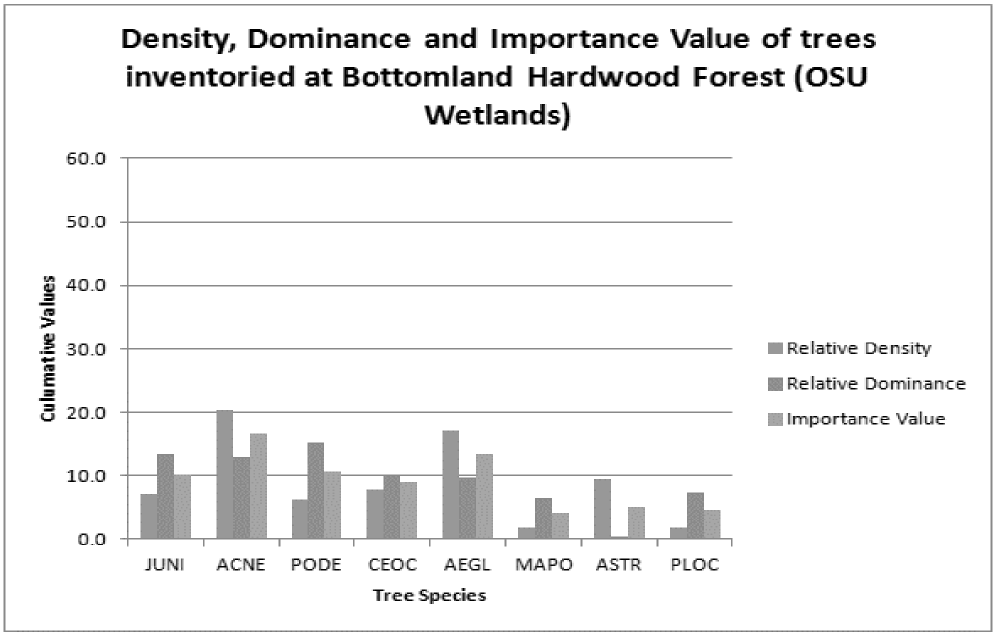

Figure 1. Relative Density, dominance and Importance Values for tree species (left to right) *Juglans nigra* (Black walnut), *Acer negundo* (box elder), *Populus deltoides* (Cottonwood), *Celtis occidentalis* (Hackberry), *Aesculus glabra* (Ohio buckeye), *Maclura pomifera* (Osage orange), *Asimina triloba* (Paw-paw), and *Platanus occidentalis* (Sycamore).

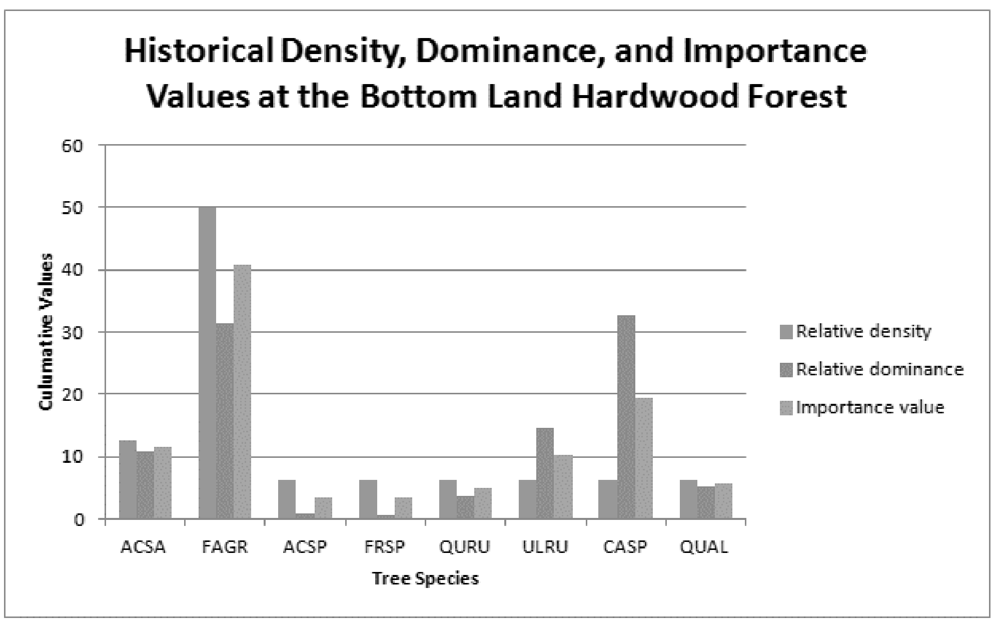

Figure 2. Relative density, dominance, and Importance Values for tree species (left to right) *Acer saccharum* (sugar maple), *Fagus grandifolia* (American beech), *Acer spp* (Maple), *Fraxinus spp* (Ash), *Quercus rubra* (Red oak), *Ulmus rubra* (Red elm), *Carya spp* (Hickory), and *Quercus alba* (White oak).

Vegetative Diversity

A total of 45 understory species were recorded over the course of the survey, in addition to 21 species of trees. The overall vegetative diversity of the forest was found to have an average Shannon's Diversity Index of 1.75 among 25 plots, with tree diversity generating an average score of 1.38 and understory diversity with 0.86. Diversity was also calculated for the fall and spring surveys, with means of 1.58 and 1.59 respectively, and using a T-test was found to not be significantly different in total diversity (p=0.41) or for understory diversity (p=0.42) (Table 1).

To quantify the change in forest diversity over the course of time, the diversity of the historical data available and a randomly generated sample of the tree survey data was calculated and compared with a T-test. The diversities of the historical (0.76) and present (0.52) tree compositions were found to be significantly different (p=0.01) (Table 2).

Table 1. Shannon's Diversity Index values by fall and spring surveys for tree and understory (total) diversity and only understory diversity at the Schiermeier Olentangy River Wetlands.

	Fall 2014		Spring 2015	
	Total Diversity	Understory Diversity	Total Diversity	Understory Diversity
Mean	1.58	0.80	1.59	0.82
STD Deviation	0.42	0.41	0.40	0.43

Table 2. Shannon's Diversity Index values found for equivalent samples of trees in the historical landscape and the Schiermeier Olentangy River Wetlands forest by plot in addition to the means, standard deviations and t-test p-values.

Sample	Historical	Present
1	1.10	0.64
2	0.69	0.87
3	0.95	0.53
4	0.64	0.54
5	0.80	0.51
6	0.74	0.41
7	0.68	0.33
8	0.50	0.36
Mean	0.76*	0.52*
STD	0.19	0.17

*- Two-tailed T-test: p=0.017

Plant Communities

After calculating Bray-Curtis dissimilarity indices and using cluster analysis on the combined spring and fall survey data, three plant community clusters were found (Figure 3). Using indicator species analysis, the three communities were named according to the most significant species which defined the community clusters (Table 3); Cottonwood-Lesser Celandine, Honeysuckle, and Ohio Buckeye-White Ash. Two plots were included in Cottonwood-Lesser Celandine community, fourteen fell under Honeysuckle, and the remaining 5 plots made up Ohio Buckeye-White Ash.

A species composition table in Appendix A represents all species found in both the fall and the spring surveys and their occurrence in the community plots. For example, if honeysuckle has a 0.6 for community 1, then it means that honeysuckle is present in 60% of community 1 plots. But if it has a 0.0 in community 3, then it was not found in any plots sorted into community 3. Appendix B contains map of survey plots categorized by community type.

Calculations were completed in R version 3.2.3 using vegan and LabDSV packages.

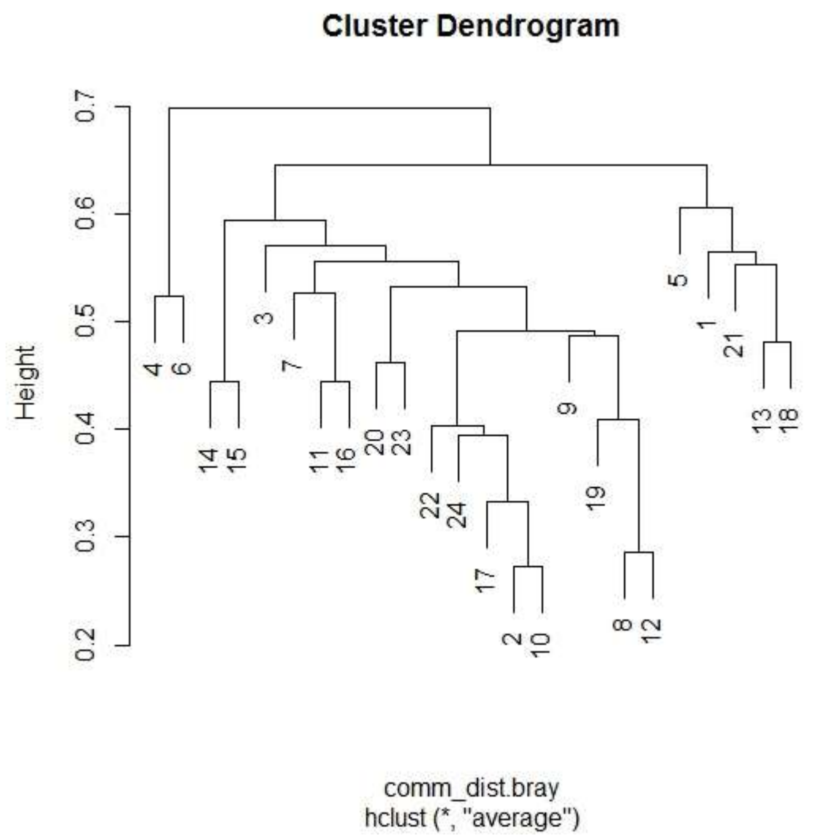

Figure 3. Dendrogram of cluster analysis results for plant community classification in bottomland forest at Schiermeier Olentangy River Wetlands. Number labels represent plot numbers. Height consists of Bray-Curtis index value. Community Clusters numbered from right to left as 1, 2, and 3.

Table 3. Most significant ($p<0.05$) indicator species from plant community analysis at Schiermeier Olentangy River Wetlands forest.

Species	Community	Indicator Value*	Probability**
Cottonwood	1	0.8947	0.001
Lesser Celandine	1	0.60	0.012
Boxelder	1	0.5667	0.017
Catalpa	1	0.5464	0.047
Honeysuckle	2	0.4764	0.044
White Ash	3	0.8947	0.009
Ohio Buckeye	3	0.5667	0.025

*- Percentage of plots in community type that the species is found.
**- The probability of finding a species more indicative of the community type.

DISCUSSION

The Current Vegetative Diversity and Composition of the Forest

Overstory Composition

Comparisons to previous studies within the study area reveal some similarities and differences between results in both tree and understory diversity. In this survey, the most important and abundant tree species found were Boxelder and Ohio Buckeye at 20% and 17% relative abundance. The Lippman 2001 survey found similar results with Boxelder holding 19% relative abundance and Ohio Buckeye with 18% abundance: the 1998 pre-restoration survey found 23% abundance for Boxelder and 15% abundance for Ohio Buckeye (Bouchard 1998). However there are some differences between surveys in the abundance of other species. The next abundant species in this survey was Paw-paw at 9.4% abundance. The 1998 survey recorded paw-paw abundance at 16%, even more than Ohio Buckeye. The 2001 survey did not record paw-paw in its survey as it focused on canopy trees with DBHs greater than 40 cm (15.7 inches), therefore it has Cottonwood at an abundance of 14% while this survey only had 6%.

However, the question remains as to what these differences mean, if they mean anything at all. The 1998 and 2001 survey both used point-quarter method and equal length transects to survey the forest, while this survey conducted a survey of the forest using circular plots in a randomly generated grid formation. This may have had an effect on the overall distribution of sampling, reaching all parts of the forest instead of emphasizing more specific areas. This survey found the greatest number of tree species (21) while the 2001 survey found 16 species and the 1998 survey found 14 species. This increase in the number of species found over time could indicate one of two things. Either that the methods used to survey canopy trees captured a greater richness of species over time, or the succession of the forest has been acquiring more species.

But many species found in this study were only represented by a few individuals, and even though this survey reveals the richness of species which can be found in an urban forest, it also supports previous findings that Boxelder and Ohio Buckeye are consistently the dominant species throughout in the whole forest while species like Paw-paw and Cottonwood are more common in certain areas of the forest.

Because of differing methods and objectives between the three studies, it is difficult to determine if the forest composition has changed in 18-year time period covered under the studies. Lippman 2001 predicted for the species composition to change towards more wetland tolerant species, such as cottonwood, based on the breaching of the levees surrounding the forest. A useful connector study between the Mitsch 1998, Lippman 2001 surveys, and this survey in 2016, is a Basal Area growth assessment completed by Anderson and Mitsch in 2008. Tree-ring analysis was used to develop a 14-year basal area increment series for 10 species in the forest and related the data to flooding events which took place before and after the release of the levees. Only boxelder was found to exhibit a significantly strong positive response to flooding events, with optimal levels estimated at 8-10 high-flood days per year, even though sugar maple and cottonwood were shown to have positive relationships with similar conditions as well. Then, only hackberry was shown to have a negative relationship with flooding of any kind while all other species did not show a response of any kind to flooding. This provides some evidence that if optimal flooding occurs in the forest in the future, then boxelder, sugar maple and cottonwood will continue to dominate the forest. Even though hydrology is a very influential process in a bottomland hardwood forest (Allen et al 2004), other factors such as regeneration competition with honeysuckle and other species could adversely affect their recruitment for the future.

Understory Composition

The understory diversity of the forest also displayed differing results among the studies. Swab 2008 monitored understory diversity both with and without the presence of honeysuckle and came to the conclusion that the presence and coverage of honeysuckle did not seem to adversely affect the diversity of the understory overall. This also seems to be supported by findings in this study as well, since the diversity in the honeysuckle vegetative community 2 was not significantly different from the overall diversity of the forest and the diversity of the other vegetative communities. This could be due to a number of factors, such as sample size and statistical error, but the limitations of this survey must be considered as well. For all diversity calculations, only species presence and absence data was used, giving a one-dimensional view of the spatial spread of the species richness of the forest but not the depth achieved by the abundance of those species in the forest. This fact does not invalidate the findings of this study, it only limits the conclusions which can be made. Also this study has captured the diversity of species present in the forest over time with surveys completed at the beginning and end of the growing seasons. Diversity is determined by factors other than biological, spatial factors such as area of habitat and connectivity through corridors are both very significant factors in increasing biodiversity (Beninde veith & Hoch Kirch 2015). Although the forest is quite small, it is part of a larger riparian corridor that runs for miles in each direction along the Olentangy River.

Long-Term Change in Composition and Diversity

When looking at longer-term changes occurring in the forest, primary reference materials such as land survey records were used in addition to previous research in the historical state of Ohio’s forest communities. Despite the information learned, the conclusions which are being made about the historical state and composition of the study area are based on a wide margin of error and uncertainty. This is due to the very nature of the data gained from the land surveys, as bias is included when choosing section corner trees and the fact that none of the section corners reside within the study area. This created a data set based on the landscape surrounding the forest study area rather than the historical bottomland hardwood forest. This fact is considered in the future discussion and provides limitations on the conclusions reached.

Records in the land survey reveal a landscape consisting of oak, hickory, walnut, beech, sugar maple, and ash with diameters ranging from 10 to 36 inches (Ohio Historical Society 1797). This provides direct data on the surrounding landscape of the area but not of the study site itself. To produce a more focused and clear picture of the tree species composition in parts of the more similar to a bottomland hardwood forest, Robert Gordon's work "The Natural Vegetation of Ohio in the Pioneer Days" (1969) was referenced. Bottomland hardwood forests are described as "wooded areas that occupy sites of recent alluvium" and are noted as being the most variable in composition compared to other forest types in Ohio (Gordon 1969). Species listed to be present in historic bottomland hardwood forests are black walnut, bitternut hickory (*Carya cordiformis*), sugar maple, sycamore, tulip tree, black cherry, pawpaw, black willow (*Salix nigra*), white ash (*Fraxinus americana*), white elm, mulberry (*Morus spp*.), locust (*Robinia spp*.), buckeye and American beech. Based upon data from the surrounding landscape, the dominant species would mainly be a beech-sugar maple mixture and codominant would be oak-hickory-black walnut. Data collected in both this study and in past studies shows that the forest is found to be mostly dominated by boxelder (*Acer negundo*), Ohio buckeye (*Aesculus glabra*) and Cottonwood (*Populus deltoides*), all of which are considered to be more early successional species in wet forests (Smith et al 2004).

Based upon the analysis of historical and current datasets, it is evident that the two time periods differ in species composition (Figure 1 and 2). The only species which overlaps between the two time periods is the Acer genus, and more specifically sugar maple. Even though the importance value of sugar maple was low in both time periods, it was the only species to be found in both datasets. In addition, there is significant difference in the accumulation of importance to the wetland forest, but this is most likely due to the limited amount of data available from historical sources and the bias nature of the data. Section corner trees were typically chosen based on their health and longevity, so certain species (such as long-lived species) would be more favored than others to be recorded and a limited number of species would be recorded. But the noticeable lack of any presence of American Beech or any long-lived species in the current survey provide some evidence that the forest has undergone a series of changes which has made the forest regress in successional development rather than advance.

Another unknown variable in determining the past forest composition and structure is the hydrology of the Olentangy River. Later it will be discussed the significance of hydrology in bottomland hardwood forest ecosystems (Allen 2004), but a centuries of human development and interference with the form and flow of the river has undoubtedly changed the river’s effects on the forest. If the forest was flooded frequently, then the common disturbance would keep the forest from being inhabited by “climax” successional species and instead anaerobic-tolerant species would be much more common. Conversely, if the river was lower than it is today, then mesic species like beech and sugar maple would have been more common in the areas on the far side of the river. Also species adapted or not adapted for hydraulic seed dispersal would be affected by changes in river hydrology and species distribution in the forest. But due to the lack in data and information, a solid conclusion on the exact state and composition of the forest cannot be known, but theorized.

The diversity of the two time periods were analyzed and compared by creating quantitatively equal data sets and calculating diversity for each. The historical data set showed a significantly higher tree species diversity than the survey in this study (p=0.001), but this is not enough evidence to assume that the historical forest indeed had greater diversity than the current forest. Firstly, there is no measure of diversity for understory species in historical record which this study could find, therefore the total diversity of the historical forest could not be determined. Additionally, the diversity of the historical data set is based upon the diversity of the landscape rather than of the study site forest. Based upon the additional notes in the survey records, the section corners fell on both uplands and lowlands, and the species recorded represented this reality (Ohio Historical Society 1797). Despite this imperfect measure, it must be pointed out that the study site is a fragment of an urban forest in a dominantly developed landscape where there is little to no forest left. This loss and fragmentation of natural habitat in addition to a plethora of environmental and biological changes both in and around the forest has been shown to decrease diversity in many ecosystems (McKenny 2002, Alvey 2006), it is not surprising nor illogical to think that there has been a loss in diversity in not just the composition of the tree species, but of the rest of the forest as well.

Future Management and Research Options

After the gathering and synthesizing of historical and modern data in addition with management and restoration suggestions from Allen’s guide for bottomland hardwood restoration (Allen 2004), a management and future restoration plan has been created consisting of three main stages. It also should be noted that this plan is created with a mostly ecological mindset and endeavors to create a plan most likely to succeed based upon scientific knowledge. Economic, time and sociological factors were not given as large of a role. It is unlikely that the plan would be fulling implementable due to extrinsic factors, but it at least lays a framework based on research done now and in the past to make more informed decisions that are more likely to be successful in restoring the health and functions of the forest.

The first stage is characterized by completing site preparation. Site preparation is a series of processed which will create improved growing conditions for desirable plant species (Allen 2004). Site preparation for a bottomland hardwood forest typically emphasizes hydrology and soil conditions (Allen 2004). The removal of levees in the forest has changed the hydrology of the forest to allow more flooding events and has been directly shown to create conditions more suitable for some native species (Anderson and Mitsch 2008) and has been shown to have a suppressive effect on the main invasive species of concern, honeysuckle (Swab, Zhang and Mitsch 2008). While site preparation has already begun with the improved hydrology of the forest, little work has been done to assess the soils present in the forest and their effects on the vegetation in conjunction with the new hydrological regime, and could be a topic of future research.

In addition to the improved hydrology of the forest to control honeysuckle, more direct mechanical control is recommended as well. Mechanical removal is more costly and has been shown to not improve native species diversity on its own (Swab, Zhang, and Mitsch 2008), but with proper planning and maintenance the removal of large honeysuckle that completely block sunlight from reaching the forest floor (Swab, Zhang and Mitsch 2008) would give other plants a greater opportunity to grow. Additional thinning of other species include boxelder and ash to open up canopy space and remove already unhealthy individuals (i.e. Emerald Ash borer victims) from the forest.

The third stage would be to plant seedlings of native trees and shrub species in the cleared areas of honeysuckle and removed canopy trees. A diverse range of native species, especially, shade-intolerant species, were chosen to plant as seedlings as they are able to grow more quickly and withstand flooding better then direct seeding (Allen 2004). In the Cottonwood-Lesser Celandine community, saplings of species such as; cottonwood, blackgum (*Nysaa sylvatica*), silver maple (*Acer saccharinum*), swamp white oak (*Quercus bicolor*), and black willow (*Salix nigra*) were chosen based on their moderate tolerance of flooding and shade. Since honeysuckle is not a dominant indicator species in these areas, these planting would serve to diversify the forest rather than suppress honeysuckle. In the Honeysuckle community where specific areas would be cleared, shade-intolerant species such as sassafras (*Sassafras albidum*), black gum (*Nyssa sylvatica*), yellow poplar (*Liriodendron tulipifera*), and black walnut (*Juglands nigra*) could be planted first to grow quickly and establish a canopy above honeysuckle height. With the decreased competition of honeysuckle and overly dominant canopy trees, the seedlings, if planted in suitable habitats, would have more sunlight and nutrients to establish and grow quickly and become part of the understory and then canopy. This process will take a decade or more, and in that time frame maintenance in the form of either honeysuckle/invasive species removal or pruning will be needed to allow saplings to establish and grow over the dense honeysuckle strata. Once a more structured canopy is established however, it is hoped that the shade from the trees in combination with the natural flooding regime would suppress the growth of honeysuckle and promote greater diversity in the understory and in the canopy. The third community of Green Ash-Buckeye was most likely unique due to the presence of live ash trees which is uncommon due to the Emerald Green Ash Borer. They are not likely to persist in the future and should be removed if hazardous to public safety. These sites can be re-evaluated and classified into the other community types to determine species selection for planting.

Conclusion

In conclusion, the Schiermeier Olentangy River Wetlands urban bottomland hardwood forest has undergone significant changes in diversity and composition since the settlement of Columbus. Results in this study and in previous studies confirm the dominance of early successional hardwood species in the present day forest. But before European settlement, the forest and the surrounding landscape was likely to have a much more diverse set of species ranging from long-lived and shade-tolerant to fast growing and shade-intolerant species suited to live in moist conditions. Because of fragmentation and continuing anthropogenic factors, it is unlikely and unwise to attempt to restore the forest to historic conditions. Instead, an informed restoration plan can be created which encourages native species regeneration, promote diversity, and control the domination of invasive species. This would restore the structure and function of the system, but would not completely restore the original species composition the historical landscape once possessed. With careful planning and implementation, the forest can be grown and developed to provide better services for both the wildlife and people who use it.

ACKNOWLEGDEMENTS

Without the help of many people, this project would have never been possible. To Anastasia Sipes, my friend and research partner, I wouldn't have made it this far without you and without you this project would have been made. To my honors advisor Dr. Roger Williams, who has supported me and my interest in Forestry and Wildlife for the past four years and helped me have unforgettable experiences both here and in China, I thank you for presenting this idea to us three years ago and letting us run with. I have learned much from you and appreciate every bit of it. To Dr. Gabriel Karns, who helped me through the struggle of stats analysis with R. Your patience and willingness to help me figure out how to solve new problems helped me analyze our data to a much greater extent than I could have alone. And finally to Dr. Alexis Londo, for helping us at the very beginning with generating our survey points in QGIS and your continual interest, help and advice with the development of the project. It's disappointing the forest map was not created, but I appreciate your willingness to help me create that and more.

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Appendix A. Vegetative Species Percent Composition and Occurrence Table by Community Type at the Schiermeier Olentangy River Wetlands forest.

Understory		Vegetative Communities		
Scientific Name	Common Name	1	2	3
Acer negundo	Boxelder (seedling)	0.4	0.06	0
Alliaria petiolata	Garlic Mustard	0.2	0.24	0
Allium schoenoprasum	Chives	0	0.06	0
Allium tricoccum	Wild Leek	0.2	0.06	0
Asarum canadense	Wild Ginger	0	0.41	0
Asimina triloba	Pawpaw (seedling)	0.2	0.06	0
Carya cordiformis	Bitternut Hickory (seedling)	0.2	0	0
Celtis occidentalis	Hackberry (seedling)	0.4	0.06	0
Dicentra cucullaria	Dutchman’s breeches	0.2	0	0
Erythronium albidum	White Trout Lily	0	0.41	0
Fraxinus americana	White Ash (seedling)	0.2	0.06	0
Fraxinus pennsylvatica	Green Ash (seedling)	0.2	0	0
Galium asprellum	Rough Bedstraw	0.2	0	0
Geranium maculatum	Wild Geranium	0.2	0.24	0
Hedera spp	Ivy	0	0.06	0
Hydrophyllum appendiculatum	Appendage Waterleaf	0.2	0.12	0
Hydrophyllum canadense	Broadleaf Waterleaf	0.2	0	0
Hydrophyllum virginianum	Virginia Waterleaf	0	0.06	0
Impatiens capensis	Jewelweed	0.6	0	0
Lindera benzoin	Spice Bush	0	0.06	0
Lonicera mackerii	Honeysuckle	0.6	0.82	0
Menispermum canadense	Moonseed	0	0.06	0
Ostyra virginiana	Hophornbeam	0.2	0	0
Parthenocissus quinquefolia	Virginia Creeper	0	0.12	0
Persicaria lapathifolia	Nodding smartweed	0	0.06	0.5
Polygonatum biflorum	Smooth Solomon’s seal	0	0.12	0
Poaceae	Grass	0	0.06	0
Ranunculus ficaria	Lesser Celandine	0.8	0.88	1
Solidago spp.	Goldenrod	0	0.12	0.5
Thalictrum thalictroides	Rue Anemone	0	0.06	0
Toxicodendron radicans	Poison Ivy	0.2	0	0
Urtica dioica	Stinging Nettle	0.2	0.24	1
Viola sororia	Common Violet	0	0	0.5
Vitis spp	Grapevine	0.4	0.12	0
Trees				
Ulmus americana	American Elm	0	0.12	0
Prunis serotina	Black Cherry	0.2	0.12	0

Robinia pseudoacacia	Black Locust	0.2	0	0
Juglans nigra	Black Walnut	0.6	0.41	0
Acer negundo	Boxelder (seedling)	1	0.76	0
Catalpa speciosa	Catalpa	0.6	0.06	0
Populus deltoides	Cottonwood	1	0.12	0
Ostrya virginiana	Eastren Hophornbeam	0	0.06	0
Fraxinus pensylvanica	Green Ash	0.2	0	0
Celtis occidentalis	Hackberry	0	0.59	0
Morus spp	Mulberry	0.4	0.35	0
Aesculus glabra	Ohio Buckeye	0	0.76	1
Maclura pomifera	Osage Orange	0.2	0.12	0
Asimina triloba	Paw-paw	0	0.12	0
Ulmus pumila	Siberian Elm	0	0.06	0
SNAG	Snag	0.6	0.53	0.5
Acer saccharum	Sugar Maple	0	0	0.5
Platinus occidentalis	Sycamore	0.4	0.12	0
Liriodendron tulipifera	Tulip Tree	0.2	0	0
Fraxinus americana	White Ash	0	0.12	1
WODO	Woody debris down	0.2	0.41	0
Salix nigra	Black Willow	0	0.06	0
Ulmus rubrum	Red Elm	0	0	0.5
Unknowns				
UN_1	Unknown 1	0.4	0.06	0
UN_2	Unknown 2	0	0	0.5
UN_3	Unknown 3	0	0	0.5
UN_4	Unknown 4	0	0.06	0
UN_5	Unknown 5	0.2	0	0.5
UN_6	Unknown 6	0	0	0.5
UN_7	Unknown 7	0	0.06	0
UN_9	Unknown 9	0	0.06	0
UN_10	Unknown 10	0	0.06	0
UN_FA	Fall Survey Unknowns	0.6	0.24	0.5

Appendix B. Map of plot points for fall 2014 and spring 2015 surveys in bottomland hardwood forest at the Schiermeier Olentangy River Wetlands with plant community categorization. Plots in Community One are labeled in green, Community Two in red and Community Three in yellow. Satellite Imagery obtained from OSIP I database.